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# Mortality among Participants in the Agricultural Health Study

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**PURPOSE:** This analysis of the Agricultural Health Study cohort assesses the mortality experience of licensed pesticide applicators and their spouses.
**METHODS:** This report is based on 52,393 private applicators (who are mostly farmers) and 32,345 spouses of farmers in Iowa and North Carolina. At enrollment, each pesticide applicator completed a 21-page enrollment questionnaire. Mortality assessment from enrollment (1994–1997) through 2000 provided an average follow-up of about 5.3 years, 447,154 person-years, and 2055 deaths.
**RESULTS:** Compared with the general population in the two states, the cohort experienced a very low mortality rate. Standardized mortality ratios (SMRs) for total mortality, cardiovascular disease, diabetes, COPD, total cancer, and cancers of the esophagus, stomach, and lung were 0.6 or lower for both farmers and spouses. These deficits varied little by farm size, type of crops or livestock on the farm, years of handling pesticides, holding a non-farm job, or length of follow up. SMRs among ever smokers were not as low as among never smokers, but were still less than 1.0 for all smoking-related causes of death. No statistically significant excesses occurred, but slightly elevated SMRs, or those near 1.0, were noted for diseases that have been associated with farming in previous studies.
**CONCLUSIONS:** Several factors may contribute to the low mortality observed in this population, including the healthy worker effect typically seen in cohorts of working populations (which may decline in future years), a short follow-up interval, and a healthier lifestyle manifested through lower cigarette use and an occupation that has traditionally required high levels of physical activity.
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KEY WORDS: Farmers, Mortality, Pesticides, Agriculture, Cancer.

## INTRODUCTION

A number of studies and reviews have documented a unique pattern of mortality among farmers (1–6). Compared with the general population, farmers appear to have a remarkable deficit in total mortality, total cancer, heart disease, lung cancer, and a number of other major causes of death. Excess mortality has been reported for accidents (7), for non-malignant respiratory conditions (8), and for a few cancers (lip, stomach, skin, eye, prostate, brain, soft-tissue sarcoma and leukemia, lymphoma, and multiple myeloma) by some (2, 3, 6), but not others (5, 9).

Although certain lifestyle factors undoubtedly contribute to some of these mortality deficits and excesses, they may not provide a full explanation. The favorable total mortality and mortality for tobacco-related diseases is heavily influenced by lower smoking rates among farmers. Farmers, however, may have contact with a number of potentially hazardous substances (10). High rates of non-malignant respiratory diseases may be due to contact with dusts, chemicals, and engine exhausts (8, 11). Excesses for certain cancers could be due to sunlight, pesticides, other chemicals, and microbes (3, 10). Fatal accidents are associated with use of machinery and working with large animals (7, 12). Because of this mixture of positive and negative risk factors, farmers and their families offer a population that may provide unique insights into disease causation and prevention. Most previous investigations, however, have used data collected for administrative rather than epidemiologic purposes, that is, death certificates, census records, tumor registries, and may have included non-farmers. Few were based on populations of farmers specifically assembled for epidemiologic investigation (13).

To more fully explain cancer and other disease patterns in agricultural populations and to identify lifestyle,

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occupational, and environmental factors associated with various health outcomes, we assembled a cohort of private and commercial pesticide applicators and spouses of private applicators in Iowa and North Carolina (14) with detailed information on lifestyle, medical, and agricultural exposures. Although we have already published on the cancer incidence of this cohort (15), this article on mortality provides an evaluation of death from cancer and non-malignant diseases.

## METHODS

The Agricultural Health Study (http://www.aghealth.org/) is a prospective study of agricultural populations in Iowa and North Carolina (14). It is composed of 57,309 licensed pesticide applicators, including 52,393 private applicators (who are almost entirely farmers), and 4916 commercial applicators from Iowa only (not included in these analyses), and 32,345 spouses of private applicators for a total of 89,654 individuals (Table 1). The applicators are mostly men (97%) and the spouses mostly women (99%). The study protocol was approved by the Human Subject's Review Boards of each collaborating agency and informed consent was obtained from study participants prior to data collection.

All applicators were eligible. Enrollment of applicators took place at county licensing facilities when each pesticide applicator was asked to complete a 21-page, enrollment questionnaire. Over 80% of the applicators completed the enrollment questionnaire. Participating applicators were given a second questionnaire covering aspects of lifestyle, pesticide application, and other agricultural activities to complete at home. Private applicators were also given a Spouse Questionnaire, used to enroll the spouse, and a Female and Family Health Questionnaire to be completed by the spouse or the occasional female applicator. Recruitment started in December 1994 and was completed in December 1997.

The applicator enrollment questionnaire sought information on crops, livestock, pesticides, pesticide application methods, use of personal protective equipment, tobacco use, alcohol consumption, fruit and vegetable intake, medical conditions, diseases among first-degree relatives, and basic demographic information. Applicator take-home questionnaires sought more detailed information on some pesticides, personal protective equipment use, various agricultural practices and tasks, diet, cooking practices, non-pesticide agricultural exposures, and jobs held off the farm. Take-home questionnaires completed by the spouses covered basic demographic and lifestyle information and included questions on pesticide use, occupations outside the home, alcohol and tobacco use, leisure-time physical activity, drinking water source, pesticide use in the home, dietary and cooking practices, and medical history. The Female and Family Health Questionnaire covered reproductive history, and some information about their children. Methodologic studies have found the reliability of reporting on lifestyle and exposure factors to be quite good (16–18).

Deaths among cohort members were identified through the National Death Index (NDI) and state mortality databases for Iowa and North Carolina from time of enrollment through 2000. Underlying causes of death, provided by the NDI, were coded according to the International Classification of Diseases rules in effect at the time of death and assigned rubrics according to the 9th revision. Less than 1% of the cohort has been lost to mortality follow up.

Standardized mortality ratios (SMRs) were calculated to compare deaths among private applicators and spouses with mortality patterns in the general population in each state. SMRs were calculated for major causes of death and selected cancers, including those previously associated with farming. Causes with less than three deaths are not presented, unless they represent diseases of special importance to farming. Commercial applicators are not included in these analyses because of the small size of this sub-cohort, the relative short follow-up period, and the younger age of this group. Expected numbers of deaths for the SMRs were developed from 5-year age and calendar-time, race, and gender-specific mortality rates for the Iowa and North Carolina populations from 1990 through 1999. Mortality rates for 2000 for Iowa and North Carolina were not available and those for 1999 were assumed to apply. Statistical significance of the SMRs was based on exact Poisson 95% confidence intervals according to Breslow and Day (19). Person-year accumulation began on date of enrollment into the cohort (date of

**TABLE 1.** Persons and person-years of follow up through 2000 by enrollment category and gender for private applicators and their spouses

| Category | Gender | Number of persons | Average age at entry | Person-years | Average years of follow-up | Average age at death | Number of deaths |
|---|---|---|---|---|---|---|---|
| Private applicators | Male | 51,034 | 47.6 | 282,407 | 5.5 | 65.9 | 1529 |
| | Female | 1359 | 48.2 | 7680 | 5.6 | 65.2 | 29 |
| Spouses | Male | 219 | 50.8 | 1211 | 5.5 | 65.4 | 15 |
| | Female | 32,126 | 47.4 | 155,855 | 4.8 | 64.3 | 482 |
| Total | | 84,738 | 47.5 | 447,154 | 5.3 | 64.5 | 2055 |

completion of the enrollment questionnaire) and ended on the closing date of this follow-up (December 31, 2000), if alive, or date of death, if deceased.

## RESULTS

The average age at entry was about 48 years. The average follow-up time was 5.3 years for this analysis (Table 1) with 447,154 person-years accumulated and 2055 deaths.

The private applicators and their spouses have mortality rates for most causes that were significantly lower than the general populations in Iowa and North Carolina (Table 2). The SMR for all-cause mortality was 0.5. Statistically significant deficits were observed for all causes, all cancers combined, and many individual causes of death including diabetes, cardiovascular disease, COPD, nephritis, suicide, and cancers of the buccal cavity and pharynx, esophagus, pancreas, lung, prostate, and bladder. No statistically significant excesses occurred. Causes of death with SMRs greater than 1.0 (and with at least three deaths) included Hodgkin's disease, and cancers of the gallbladder, eye, and thyroid. Mortality patterns were largely similar for applicators and spouses, but spouses had slight excesses of NHL, leukemia, and cancers of the stomach, colon, liver, soft tissue, and brain. Applicators had nonsignificant excesses for Hodgkin's disease, and cancers of the thyroid and female genital organs that did not occur among spouses.

SMRs for applicators were based primarily on mortality among men and for spouses primarily among women. There were only 29 deaths among female applicators and they resulted in SMRs of 0.5 (95% CI, 0.3–0.7) for all causes, 0.7 (95% CI, 0.4–1.2 based on 12 deaths) for all cancer, 3.9 (95% CI, 1.1–10.1, based on four deaths) for ovarian cancer, 2.8 (95% CI, 0.3–10.1 based on two deaths) for NHL, and 2.2 (95% CI, 0.2–7.8, based on two deaths) for non-motor

**TABLE 2.** Mortality in the AHS cohort through 2000 for selected causes of death by enrollment category (expected based on general population mortality rates in Iowa and North Carolina)

| | Private applicators | | Spouses | | Total | |
|---|---|---|---|---|---|---|
| Cause of death | Deaths | SMR (95 % CI) | Deaths | SMR (95% CI) | Deaths | SMR (95% CI) |
| All causes | 1558 | 0.5 (0.4–0.5) | 497 | 0.6 (0.5–0.6) | 2,055 | 0.5 (0.5–0.5) |
| All cancers | 514 | 0.6 (0.5–0.6) | 239 | 0.7 (0.6–0.8) | 753 | 0.6 (0.6–0.7) |
| Buccal cavity and pharynx | 5 | 0.3 (0.1–0.7) | 0 | 0 (0–25.4) | 5 | 0.3 (0.1–0.6) |
| Digestive system | 145 | 0.7 (0.6–0.8) | 56 | 0.9 (0.7–1.2) | 201 | 0.7 (0.6–0.8) |
| Esophagus | 16 | 0.5 (0.3–0.9) | 1 | 0.3 (0.1–1.9) | 17 | 0.5 (0.3–0.8) |
| Stomach | 10 | 0.5 (0.2–1.0) | 4 | 1.1 (0.3–2.8) | 14 | 0.6 (0.3–1.0) |
| Colon | 56 | 0.7 (0.6–1.0) | 31 | 1.2 (0.8–1.6) | 87 | 0.8 (0.7–1.0) |
| Liver | 8 | 0.6 (0.2–1.1) | 4 | 1.7 (0.4–4.3) | 12 | 0.7 (0.4–1.3) |
| Gallbladder | 3 | 2.0 (0.4–5.7) | 2 | 1.3 (0.1–4.6) | 5 | 1.6 (0.5–3.8) |
| Pancreas | 29 | 0.6 (0.4–0.9) | 10 | 0.7 (0.3–1.2) | 39 | 0.7 (0.5–0.9) |
| Lung | 129 | 0.4 (0.3–0.4) | 29 | 0.3 (0.2–0.5) | 158 | 0.4 (0.3–0.4) |
| Soft tissue | 4 | 0.7 (0.2–1.8) | 3 | 1.4 (0.3–4.1) | 7 | 0.9 (0.4–1.8) |
| Melanoma | 13 | 0.7 (0.4–1.3) | 2 | 0.4 (0.1–1.6) | 15 | 0.7 (0.4–1.1) |
| Breast | 3 | 0.9 (0.2–2.7) | 54 | 0.9 (0.7–1.1) | 57 | 0.9 (0.7–1.2) |
| Female genital | 4 | 2.1 (0.6–5.5) | 25 | 0.7 (0.5–1.1) | 29 | 0.8 (0.5–1.2) |
| Ovary | 4 | 3.9 (1.1–10.1) | 13 | 0.7 (0.4–1.2) | 17 | 0.9 (0.5–1.4) |
| Prostate | 48 | 0.7 (0.5–0.8) | 0 | 0 (0–1.6) | 48 | 0.7 (0.5–0.9) |
| Bladder | 7 | 0.4 (0.1–0.7) | 2 | 0.8 (0.1–2.7) | 9 | 0.4 (0.2–0.8) |
| Eye | 2 | 2.1 (0.2–7.6) | 1 | 3.7 (0.1–20) | 3 | 2.5 (0.5–7.2) |
| Brain | 19 | 0.7 (0.4–1.1) | 11 | 1.1 (0.5–1.8) | 30 | 0.8 (0.5–1.1) |
| Thyroid | 3 | 1.8 (0.4–5.3) | 0 | 0 (0–2.2) | 3 | 1.3 (0.2–3.7) |
| NHL | 33 | 0.9 (0.6–1.2) | 16 | 1.2 (0.7–2.0) | 49 | 1.0 (0.7–1.3) |
| Hodgkin's disease | 3 | 1.7 (0.3–4.8) | 0 | 0 (0–2.5) | 3 | 1.1 (0.2–3.3) |
| Myeloma | 11 | 0.6 (0.3–1.2) | 5 | 0.9 (0.3–2.1) | 16 | 0.7 (0.4–1.2) |
| Leukemia | 27 | 0.8 (0.5–1.1) | 14 | 1.4 (0.8–2.4) | 41 | 0.9 (0.6–1.2) |
| Diabetes | 26 | 0.3 (0.2–0.5) | 18 | 0.6 (0.4–1.0) | 44 | 0.4 (0.3–0.6) |
| Cardiovascular disease | 537 | 0.5 (0.5–0.6) | 82 | 0.4 (0.3–0.5) | 619 | 0.5 (0.5–0.6) |
| COPD | 35 | 0.2 (0.1–0.3) | 15 | 0.3 (0.2–0.7) | 50 | 0.2 (0.2–0.3) |
| Nephritis | 9 | 0.4 (0.2–0.7) | 6 | 0.9 (0.3–2.0) | 15 | 0.5 (0.3–0.8) |
| Motor vehicle accidents | 56 | 0.8 (0.2–1.0) | 14 | 0.8 (0.4–1.3) | 70 | 0.8 (0.6–1.0) |
| Non-motor vehicle accidents | 74 | 1.0 (0.8–1.2) | 8 | 0.6 (0.3–1.2) | 82 | 0.9 (0.7–1.1) |
| Suicide | 46 | 0.6 (0.5–0.9) | 7 | 0.7 (0.3–1.5) | 53 | 0.6 (0.5–0.8) |

SMRs adjusted for calendar year of death, age, state, race, and gender.

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vehicle accidents. Male spouses experienced 15 deaths and resulted in SMRs of 0.9 (95% CI, 0.5–1.5 based on 15 deaths) for all causes, 1.0 (95% CI, 0.3–2.4 based on five deaths) for all cancers, and 1.6 (95% CI, 0.3–4.7 based on three deaths) for lung cancer.

The mortality for most causes of death was quite similar in the two states with large deficits for all causes, all cancers, lung cancer and cardiovascular disease (data not shown).

Table 3 displays SMRs for selected causes of death among private applicators stratified by presence of livestock or corn on the farm, farm size, and duration of handling pesticides. There were no obvious mortality differences across these strata, although the numbers of events were small for many categories. Table 4 shows SMRs for selected causes of death by cigarette use, strenuous non-occupational summer exercise, off-farm employment, and follow-up period.The lower SMRs among never smokers than ever smokers for many causes of death were to be expected. For example, all-cause and all-cancer SMRs were less than one for both nonsmokers and ever smokers, but the deficits are considerably larger among nonsmokers. Individuals who reported they engaged in strenuous leisure-time exercise for more than 1 hour per week had lower SMRs for all causes combined, cancers of the colon, breast, prostate, and brain, and cardiovascular disease than those who exercised for less than 1 hour per week. Holding a non-farm job did not appear to impact the mortality from any disease. The SMRs for the first 2 years of follow-up and most recent 2 years were similar for most causes, although there might be a slight increase in the recent period.

## DISCUSSION

This initial evaluation of the deaths among private pesticide applicators (almost entirely farmers) and their spouses participating in the Agricultural Health Study indicates they experience a very favorable mortality compared with the general populations of Iowa and North Carolina. This is consistent with the published literature on farmers (1–3, 5). The deficits for overall mortality and a number of selected diseases in this cohort, however, are somewhat greater than previously reported. The mortality pattern was similar in the two states and did not vary much by farm size, type of farm operation, years of handling pesticides, or holding non-farm jobs. Although nonsmoking participants had lower SMRs than smokers for tobacco-related causes of death, it is striking that even smokers had lower mortality rates for these diseases than the general population. Those engaging in more frequent strenuous leisure-time physical activity tended to have lower SMRs for a number of causes than those with lesser activity, although these differences were not statistically significant. Leisure-time exercise may be a poor measure of physical activity for farmers who traditionally perform many physically demanding tasks associated with their farm activities.

Some of the observed deficits are undoubtedly due to the well-documented healthy worker effect observed when working cohorts are compared with the mortality experience of the general population (20, 21). This is likely to contribute to the mortality deficits among the applicators, but might be less important among the spouses. The healthy worker effect, however, complicates interpretation and

**TABLE 3.** Mortality among private applicators in the AHS cohort through 2000 by type of farm and exposure (expected based on general population rates in Iowa and North Carolina)

| | Grew corn | | | | Had animals (Other than poultry) | | | | Farm size (Acres) | | | | Years handled pesticides | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No | | Yes | | No | | Yes | | <200 | | ≥200 | | ≤10 | | 11+ | |
| Cause of death | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR |
| All causes | 669 | 0.6* | 889 | 0.4* | 946 | 0.6* | 612 | 0.4* | 610 | 0.5* | 541 | 0.4* | 313 | 0.5* | 1010 | 0.5* |
| All cancers | 220 | 0.7* | 294 | 0.5* | 308 | 0.6* | 206 | 0.5* | 203 | 0.6* | 183 | 0.5* | 99 | 0.6* | 337 | 0.5* |
| Colon | 13 | 0.5* | 43 | 0.8 | 30 | 0.8 | 26 | 0.7 | 18 | 0.7 | 22 | 0.7 | 8 | 0.6 | 39 | 0.7* |
| Pancreas | 8 | 0.5 | 21 | 0.7 | 15 | 0.6 | 14 | 0.6 | 9 | 0.6 | 16 | 0.8 | 26 | 0.4* | 26 | 0.8 |
| Lung | 67 | 0.5* | 62 | 0.3* | 87 | 0.5* | 42 | 0.3* | 46 | 0.3* | 40 | 0.3* | 25 | 0.4* | 80 | 0.3* |
| Prostate | 24 | 0.8 | 24 | 0.6* | 29 | 0.7 | 19 | 0.6 | 21 | 0.7 | 13 | 0.5* | 10 | 0.7 | 30 | 0.6* |
| Brain | 8 | 0.9 | 11 | 0.6 | 11 | 0.8 | 8 | 0.6 | 9 | 1.0 | 6 | 0.4* | 5 | 0.9 | 12 | 0.6 |
| NHL | 14 | 1.0 | 19 | 0.8 | 17 | 0.9 | 16 | 0.9 | 14 | 1.0 | 15 | 0.9 | 10 | 1.4 | 22 | 0.8 |
| Myeloma | 5 | 0.8 | 6 | 0.6 | 8 | 0.9 | 3 | 0.4 | 4 | 0.6 | 4 | 0.6 | 1 | 0.3 | 1 | 0.6 |
| Leukemia | 11 | 0.9 | 16 | 0.7 | 19 | 1.0 | 8 | 0.5* | 13 | 1.0 | 9 | 0.6 | 7 | 1.0 | 22 | 0.8 |
| Cardiovascular dis. | 222 | 0.6* | 315 | 0.5* | 322 | 0.6* | 215 | 0.5* | 219 | 0.6* | 184 | 0.5* | 106 | 0.6* | 355 | 0.5* |
| COPD | 17 | 0.2* | 18 | 0.2* | 30 | 0.3* | 5 | 0.1* | 14 | 0.2* | 7 | 0.2* | 8 | 0.2* | 23 | 0.2* |
| Non-motor vehicle accidents | 18 | 0.9 | 56 | 1.1 | 29 | 0.8 | 45 | 1.2 | 22 | 0.9 | 39 | 1.1 | 17 | 0.9 | 48 | 1.0 |

*95% confidence interval does not include 1.0.
SMRs adjusted for calendar year of death, age, state, race, and gender.

**TABLE 4.** Mortality among private applicators and spouses in the AHS cohort through 2000 by lifestyle characteristics and follow-up period (expected based on general population rates in Iowa and North Carolina)

| | Ever used cigarettes | | | | Strenuous leisure time summer exercise | | | | Ever held non-farm job | | | | Follow-up period | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No | | Yes | | ≤1 Hour | | >1 Hour | | No | | Yes | | Through 1998 | | 1999–2000 | |
| Cause of death | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR | Deaths | SMR |
| All causes | 748 | 0.4* | 1131 | 0.6* | 637 | 0.6* | 446 | 0.4* | 348 | 0.5* | 838 | 0.5* | 1157 | 0.5* | 898 | 0.6* |
| All cancers | 296 | 0.5* | 405 | 0.7* | 247 | 0.7* | 197 | 0.6* | 140 | 0.6* | 351 | 0.6* | 415 | 0.6* | 338 | 0.7* |
| Colon | 45 | 0.9 | 35 | 0.8 | 31 | 1.0 | 23 | 0.8 | 19 | 0.9 | 42 | 0.9 | 47 | 0.8 | 40 | 1.0 |
| Pancreas | 16 | 0.5* | 23 | 0.8 | 11 | 0.6 | 14 | 0.8 | 7 | 0.6 | 22 | 0.9 | 25 | 0.7 | 14 | 0.6* |
| Lung | 14 | 0.1* | 134 | 0.6* | 45 | 0.4* | 35 | 0.3* | 24 | 0.3* | 59 | 0.3* | 90 | 0.4* | 68 | 0.4* |
| Breast | 35 | 0.7 | 16 | 1.0 | 27 | 1.2 | 18 | 0.7 | 6 | 0.6 | 46 | 0.9 | 39 | 1.1 | 18 | 0.7 |
| Prostate | 17 | 0.6* | 27 | 0.7 | 15 | 0.7 | 9 | 0.5* | 11 | 0.7 | 14 | 0.6 | 29 | 0.7* | 19 | 0.6* |
| Brain | 21 | 1.1 | 5 | 0.3* | 10 | 0.9 | 4 | 0.4* | 6 | 0.9 | 11 | 0.6 | 15 | 0.6 | 12 | 0.6 |
| NHL | 27 | 1.1 | 22 | 1.0 | 12 | 0.8 | 17 | 1.2 | 8 | 0.8 | 24 | 1.1 | 29 | 1.0 | 20 | 1.0 |
| Myeloma | 7 | 0.6 | 7 | 0.7 | 5 | 0.8 | 3 | 0.5 | 1 | 0.2 | 7 | 0.7 | 12 | 0.9 | 4 | 0.4 |
| Leukemia | 20 | 0.9 | 18 | 0.9 | 13 | 1.0 | 13 | 1.0 | 7 | 0.8 | 21 | 1.1 | 21 | 0.8 | 20 | 1.1 |
| Cardiovascular disease | 210 | 0.4* | 352 | 0.6* | 185 | 0.5* | 109 | 0.3* | 106 | 0.4* | 204 | 0.4* | 359 | 0.5* | 260 | 0.5* |
| Non-motor vehicle accidents | 34 | 0.8 | 43 | 1.1 | 19 | 0.9 | 18 | 0.8 | 12 | 0.8 | 27 | 0.8 | 57 | 1.0 | 25 | 0.7 |

*95% confidence interval does not include 1.0.
SMRs adjusted for calendar year of death, age, state, race, and gender.

without some adjustment means that true excesses could be entirely missed and others diminished against this back drop of low mortality. We chose not to make a formal adjustment, such as dividing cause-specific SMRs by the total mortality SMR, but we do recognize that SMRs for some individual causes of death may be artificially low. It would be preferable to have another working population from these two states for comparison, but no such group is available. The healthy worker effect is typically the strongest during the early years of cohort follow-up and moderates over time (21, 22). Such moderation may occur in the Agricultural Health Study cohort as follow-up continues. We calculated SMRs for follow up through 1998 and for 1999 to 2000. Although the SMRs for all causes of death rose from 0.5 to 0.6 and all cancer from 0.6 to 0.7, these differences are small and the follow-up is really too short to draw meaningful comparisons at the present time. The major objective of the AHS, however, is to evaluate the impact of specific agricultural practices, exposures, and lifestyle factors on disease risk and this can be accomplished using internal comparisons, for example, comparing exposed and unexposed farmers, which largely removes the healthy worker effect present in comparisons with the general population. The purpose of this article, however, was to provide data on the mortality experience relative to the general population, rather than identify risk factors for specific diseases.

Farm families engage in a number of positive health habits that have a beneficial impact on mortality rates. Many of these traits are found in rural populations whether engaged in farming or not. Stiernstrom et al. (23) found that for several causes of death among farmers and non-farming rural residents, mortality rates were similar and considerably lower than urban residents. Non-farming rural residents did have a slightly higher mortality rate than farmers for all tumors combined. Tobacco use among farmers is less than for urban populations (3). Only 15% of farmers in the cohort and 10% of their spouses were tobacco users at the time of enrollment (14). Smoking rates were low even in North Carolina where tobacco is an important crop. This compares to 26% of the men and 21% of the women who are smokers in the general population in Iowa and 28% among men and 21% among women from North Carolina (24). These differences, however, would not explain why smokers in the AHS cohort have lower mortality for many tobacco-related causes of death than the general population, which is a combination of rates among smokers *and* nonsmokers. Other factors must be involved. Alcohol use did not appear fundamentally different among the cohort and general population. Thirty-four percent of the farmers and 44% of their spouses reported they had not used alcohol during the past year compared with 31% among men and 44% among women in the United States (25). Farmers may, however, be more physically active than individuals in other occupations. Physical activity is known to be protective against a number of chronic diseases, including coronary heart disease, diabetes, cancers of the colon and breast, and perhaps other malignancies (26). Farming typically requires a considerable amount of physical activity and was the explanation for the lower levels of heart disease observed among farmers in studies in Georgia and Iowa (27, 28). The low prevalence of smoking, alcohol use, and physical inactivity would lead to lower mortality rates for several

major causes of death including cardiovascular disease, stroke, and cancers of the lung, colon, mouth and throat, liver, pancreas, bladder, and kidney (26, 29, 30).

Several previous incidence and mortality studies of farmers have reported excesses for cancers of the lip, stomach, skin, brain, and prostate and lymphatic and hematopoietic system (1–3, 9, 31–37). We observed no statistically significant mortality excesses for any cancer in the Agricultural Health Study cohort after 5.3 years of follow-up and there were only a few SMRs of 1.0 or larger, including cancers of the gallbladder and eye among applicators and spouses; non-motor vehicle accidents, Hodgkin's disease and cancers of the thyroid, and female genital organs among applicators; and NHL, leukemia, soft tissue sarcoma and cancers of the stomach, colon, liver, and brain among spouses. Some of the cancers with small excesses were cancer sites (i.e., eye, stomach, NHL, myeloma, soft-tissue sarcoma, and leukemia) that have been reported as excessive in previous investigations of farming populations (3, 31–33). These small excesses are somewhat more impressive when considered in light of the very low overall mortality for this cohort. As with mortality, cancer incidence rates among applicators and spouses in this cohort are generally lower than the general population (15).

Historically, rates of injuries and accidental death rates among farmers are among the highest for any occupational group (3, 7, 38) and farmers rank number 12 among the 50 highest rate occupations for fatal injury (39). It is not clear why we found an SMR of only 1.0 for non-motor vehicle accidents among applicators and an SMR of 0.6 among spouses, although Acquavella and Olsen (5) did not see an excess in their meta-analysis of mortality among farmers. It could be that Iowa and North Carolina farmers have lower accident rates than farmers elsewhere. Zwerling et al. (40), however, found excess mortality from accidents among Iowa farmers in the 1980s and agriculture ranked high for fatal occupational injuries among self-employed workers in North Carolina (41). There is some evidence that rates of fatal occupational injuries are declining in the agricultural sector (42, 43) and this study of mortality in the late 1990s may reflect this pattern.

In summary, private applicators (mostly farmers) and farmers' spouses participating in the Agricultural Health Study have a very low overall mortality. A more careful evaluation of this population is warranted to identify environmental and lifestyle factors in the agricultural environment that may contribute to these deficits. There are a few causes of death with slight excesses that deserve attention as the cohort ages when there will be larger numbers for analysis and the impact of the healthy worker effect moderates. The combination of very low mortality for many causes of death and possible excesses for a few causes of death make this a valuable cohort to identify factors associated with good and ill health.

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